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(54) **Airtight seal structure of low melting point glass to be used in optical fiber guiding portion of optical device and method of airtight seal using low melting point glass.**

(57) An airtight sealing method for a leading portion of an optical fiber (1), which provides high airtight sealing effect and is suitable for mass-production, is provided. The airtight seal structure of a leading portion of an optical fiber according to the present invention comprises an optical fiber (1) and a metal pipe (4) having a through-whole for receiving the optical fiber and adapted to connect an inner portion of the leading portion to an outer portion of the leading portion. A pair of glass pipes(5) each having a through-hole receives the optical fiber and is adapted to be inserted into the metal pipe. A low melting point glass material (3) is disposed between the glass pipes in the metal pipe and seals the inner and outer portions of the leading portion by filling a space between an inside of the metal pipe and the optical fiber when heated. Particularly, the melting point of the glass pipes is higher than the melting point of the low melting point glass material so that they are sealed by the low melting point glass material and fixedly bonded to an inner wall of the metal pipe when the low melting point glass material becomes molten state by heating.

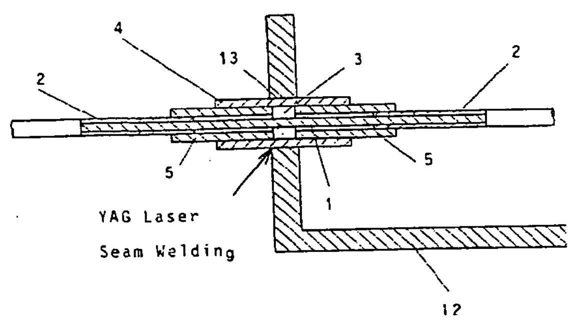

FIG. 7

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The present invention relates to a method of forming an airtight seal structure to be used in an optical fiber guiding portion of an optical device having optical fibers.

In general, an optical device such as semiconductor optical module, $LiNbO_3$ optical waveguide device and light activated device, which is used in an optical fiber communication device, is encapsulated airtightly by a casing of such as anti-corrosive stainless steel, in order to prevent an optical semiconductor element or optical waveguide element from being influenced by moisture. Further, in order to completely sealing the whole casing externally, it is also necessary to airtightly seal an optical fiber guiding portion of the casing.

In order to completely protect the optical semiconductor element, etc., against external moisture, airtightness in the order of 10^{-8} atm.cc/sec is required. When the casing is composed of a metal case body and a metal cover thereof, airtightness in such order can be relatively easily achieved since the seam welding technique can be applied and airtight seal of electrode terminal portion is also easily achieved by fixing a lead portion thereof by glass.

For an optical fiber guiding portion thereof, airtight seal is difficult since the optical fiber is of silicon oxide which is fragile and easily broken. Since the optical fiber has a protective sheath of resin, it is impossible to apply the seam welding directly. Therefore, it is usual to airtight seal such portion by fixing the sheath of the optical fiber with using adhesive resin (this will be referred as "first" method). In this first method, however, airtightness obtainable is as low as in the order of 10^{-5} atm.cc/sec which is not enough to obtain an acceptable reliability of the optical device.

As a second method for achieving high airtightness of the optical fiber guiding portion, Japanese Patent Application Laid-open No. Sho 57-68937 discloses a technique in which an optical fiber is covered by a metal material such as gold and the metal cover is soldered to a surrounding metal pipe. This technique makes it possible to obtain an airtight seal as high as substantially the same degree of the seam weld technique and, therefore, a high reliability of optical device can be obtained. In this case, however, the metal cover or coating of the optical fiber is indispensable and a vapor-deposition of such metal coating on an optical fiber is relatively complicated, leading to high manufacturing cost.

As a third technique, a direct fixing of an optical fiber to a metal pipe by means of a low melting point glass has been proposed which will be referred to as a third technique. It has been known that the melting point of such low melting point glass is about 500°C. With such high temperature, an optical fiber may be subjected to microbending by which optical characteristics of optical fiber may be degraded.

As a fourth conventional technique, Japanese Patent Application Laid-open No. Hei 5-241028 discloses an optical fiber having a protective coating formed of ultraviolet setting resin. In this technique, when the optical fiber is heated, its optical characteristics is not degraded since there is no thermal stress in the optical fiber although the ultraviolet setting resin is burnt. Therefore, it is possible to airtightly seal the optical fiber without thermal stress. In this technique, however, there may be a case where the optical fiber is partially exposed at a portion on which the resin coating is burnt out.

An object of the present invention is to provide an airtight sealing method for a leading portion of an optical fiber, which includes relatively simple processing steps and provides high airtight sealing effect without adverse influence of melting heat of a low melting point glass.

Another object of the present invention is to provide an airtight sealing method for a leading portion of an optical fiber, by which partial exposition of optical fiber is prevented and any reinforcing step is unnecessary.

An airtight seal structure of a leading portion of an optical fiber according to the present invention comprises an optical fiber and a metal pipe having a through-hole for receiving the optical fiber and adapted to connect an inner portion of the leading portion to an outer portion of the leading portion. A pair of glass pipes each having a through-hole receives the optical fiber and adapted to be inserted into the metal pipe. A low melting point glass material is disposed between the glass pipes in the metal pipe and seals the inner and outer portions of the leading portion by filling a space between an inside of the metal pipe and the optical fiber when heated.

Particularly, the melting point of the glass pipes is higher than the melting point of the low melting point glass material so that they are sealed by the low melting point glass material and fixedly bonded to an inner wall of the metal pipe when the glass material becomes molten state by heating.

The airtight seal structure of a leading portion of an optical fiber according to the present invention minimizes length of a terminal end portion of the airtightly sealed optical fiber without any exposed portion of the optical fiber. Length of the metal pipe is as small enough to fix low melting point glass material as possible. A portion of the optical fiber which is exposed is protect d by the glass pipes. According to th m thod of the present invention, the glass pipes whose melting point is higher than that of th low melting point glass material are insert d into the trouble-hole of the metal pipe and th metal pip is heat d to m lt the low melting point glass mat rial. Th refore, there is no heat transmission to th prot ctive coating by conv ction of air as in th conventional techniques. Further, flow of h at is prevent d by the glass pipes, so that influence of h at to th

protective coating is restricted to minimum.

The low m lting point glass material in molt n state functions to not only fix th optical fiber to the metal pipe but also fix the glass pipes to the metal pip . A similar effect of blocking heat flow can be obtained by means of ceramic pipes instead of the glass pipes. However, in the latter case, it is impossible to fix the ceramic pipes to a metal pipe by low melting point glass material. Further, since thermal conductivity of ceramic pipe is larger than that of glass pipe, the blocking effect of heat flow is not so large as that of the glass pipe. In addition thereto, by putting an exposed portion of the optical fiber within the glass pipes, it is possible to manufacture an airtightly sealed optical fiber which can be easily handled. Therefore, there is no need of protect the optical fiber by resin, etc., separately, and thus it is possible to supply airtightly sealed optical fiber terminals which can be easily handled. The glass pipes as they are can be used for positioning of the optical fiber, making any ceramic pipe unnecessary. The invention will be further described in connection with the drawings, in which:

Fig. 1 is a longitudinal cross section of a conventional optical fiber leading portion, showing a conventional airtight seal therefor;

Fig. 2 is a longitudinal cross section of another conventional optical fiber leading portion, showing another conventional airtight seal therefor;

Fig. 3 is a longitudinal cross section of an optical fiber leading portion according to a first embodiment of the present invention before a low melting point glass is melted, showing an airtight seal therefor;

Fig. 4 is a longitudinal cross section of the optical fiber leading portion shown in Fig. 1 after the low melting point glass material is melted and fixed;

Fig. 5 is a perspective view of an optical fiber leading portion of the present invention, showing an airtight sealing of the portion by using a high frequency induction heater according to an embodiment of the present invention;

Fig. 6 is a graph showing a relation between heating condition and finished state of the airtightly sealed portion;

Fig. 7 is a longitudinal cross section of an optical fiber whose airtight seal portion is fixed to a casing by the manufacturing method of the optical fiber leading portion according to the present invention; and

Fig. 8 is a longitudinal cross section of an optical fiber leading portion, showing an airtight sealing method according to a second embodiment of the present invention.

Among the conventional methods mentioned previously, the third and fourth methods will be described in detail. Fig. 1 shows an airtight seal portion provided by the third method, in which the optical fiber is directly fixed to the metal pipe by means of low melting point glass material. In this method, an optical fiber 1 is partially exposed by peeling off a portion of its protective coating 8 of such as nylon resin. Then, the exposed portion of the optical fiber 1 is inserted into a pipe shaped tablet 3 of low melting point glass material and the tablet 3 is inserted into a metal pipe 4. A ceramic pipe 7 having a positioning through-hole is pressure-inserted into an end portion of the metal pipe 4 in order to prevent the optical fiber 1 from leading within the metal pipe. In this state, the metal pipe 4 is heated by a high frequency induction heater 6 to heat the low melting point glass material 3 in the metal pipe 4 to a certain temperature which is high enough to melt the low melting point glass material. Thermal expansion coefficient of the metal pipe 4 is larger than that of the low melting point glass material 3 which is larger than that of the optical fiber 1. Therefore, when the heating terminates, the metal pipe 4 contracts to press the low melting point glass material 3 which contracts to press the optical fiber 3. Thermal expansion coefficient of the metal pipe 4 of SUS304 is 180×10^{-7}, that of the low melting point glass material 3 is approximately 50×10^{-7} and that of the optical fiber 1 is 5×10^{-7}. Due to the differences in thermal expansion coefficient between the metal pipe 4, the low melting point glass 3 and the optical fiber 1, a strong compressive force is produced with which the optical fiber 1, the low melting point glass material 3 and the metal pipe 4 can be completely intimately fixed to each other, resulting in an optical fiber terminal sealed airtightly enough to guarantee a high reliability of an optical device.

Fig. 2 shows an airtight seal portion provided by the fourth method, in which an optical fiber 1 has a protective coating 10 of ultraviolet setting resin which is hardened when irradiated with ultraviolet ray. In this method, when the optical fiber 1 is heated by a high frequency induction heater 6, only the protective coating 10 is burnt out and there is no thermal stress produced in the optical fiber 1. Therefore, optical characteristics of the optical fiber 1 is not degraded. In the example shown in Fig. 2, the high frequency induction heater 6 is used to manufacture an airtightly sealed optical fiber terminal so that an exposed portion of the optical fiber 1 does not become unnecessarily long. That is, l ngth of the expos d portion of the optical fiber 1 is mad equal to length f a pipe shaped tablet 3 of low melting point glass material so that the metal pipe 4 cov rs the ultraviolet s tting r sin coating 10 partially. Th metal pip 4 in such state is heated to melt the low melting point glass material 3. H at is conducted to portions of the resin coating 10 which are covered by the m tal pip 4 from the metal pipe 4 through air or a ceramic pip 7 pressure-inserted into one end of the metal pip

4 and the portions of the resin coating 10 are not shrunk as the nylon resin coating 8 in Fig. 1 but burnt out. The burnt portions of the resin coating 10 is indicated by 10a. Therefore, it is possible to airtightly fix the optical fiber 1 to the metal pipe 4 by m ans of the low melting point glass material 3 without ex rting thermal stress on the optical fiber 1. In this case, it should be noted, however, that the optical fiber 1 may be exposed at the burnt portions 10a.

In the third method mentioned previously, the exposed portion of the optical fiber may be easily broken or damaged. Further, it is necessary to remove an influence of heat used to heat the metal pipe on the optical fiber.

On the other hand, in the fourth method mentioned above in which the protective coating is burnt out by heating, it is indispensable that portions of the protective coating outside the metal pipe may also be burnt out, so that even portions of the optical fibers which correspond to the burnt out portions of the protective coating outside the metal pipe may be exposed. Therefore, the reliability of the optical fiber after fixed by the low melting point glass material becomes very low.

Now, the airtight seal method of the optical fiber lead portion according to the present invention which solves the above-mentioned problems of the conventional method will be described with reference to Figs. 3 to 5.

Figs. 3 and 4 are longitudinal cross sections of the optical fiber lead portion before low melting point glass material is melted and after the low melting point glass material is melted and fixes the optical fiber in a metal pipe, respectively. First, as shown in Fig. 3, a portion of a protective coating 2 of an optical fiber 1, which may be of ultraviolet setting resin, is peeled off to expose the optical fiber 1. The optical fiber 1 is inserted into a glass pipe 5, a pipe shaped tablet 3 of low melting point glass and another glass pipe 5, in the sequence, such that the tablet 3 is positioned on the exposed portion of the optical fiber 1. Then, the assembly is inserted into a metal pipe 4 with the tablet 3 being at a center position of the metal pipe 4 and with the glass pipes 5 being partially exposed from opposite ends of the metal pipe 4, respectively. The metal pipe 4 is then heated locally by a high frequency induction heater. Fig. 5 is a perspective view showing the local heating of the metal pipe 4. In Fig. 5, the metal pipe 4 of the assembly is put in the high frequency induction heater 6. Wgen the metal pipe 4 is heated locally in this manner, the tablet 3 of low melting point glass material is melted and fixes the optical fiber 1 and the glass pipes 5 to the metal pipe 4.

In this method, heating time and temperature are important parameters in heating low melting point glass material through the metal pipe and these parameters should be selected such that low melting point glass material is reliably melted while giving no influence to the optical fiber. Fig. 6 shows a finish of the airtight seal portion when heating condition is changed. In Fig. 6, the heating condition selected from a hatched area A is enough to reliably melt the low melting point glass and the heating condition selected from a hatched area B is enough to avoid influence of heat to the optical fiber. Therefore, the heating condition within a cross hatched area satisfies the requirement of the present method. A white circle in the cross hatched area shows the heating condition used in this embodiment.

Describing this in detail, the airtight seal portion is formed under condition of temperature at about 550°C and heating time of 30 seconds. At temperature 550°C, when the heating time is 20 seconds or shorter, low melting point glass is not melted sufficiently. On the other hand, when the heating time exceeds 60 seconds at the same temperature, the optical fiber 1 is infouenced by heat. Therefore, at the temperature of 550°C, the heating time may be set between 20 seconds and 60 seconds.

When the airtight seal is prepared by heating the whole assembly in a heating furnace at 440°C, it takes 10 minutes. In the present embodiment in which low melting point glass is melted by local heating, the heating condition was set at a higher temperature and a shorter heating time than those in the case of the heating furnace in view of avoidance of thermal influence to the optical fiber. As to the temperature of about 550°C, it was selected for the reasons that, at 500°C, it takes about 3 minutes to melt low melting point glass 3 sufficiently, that, at 600°C or higher, although low melting point glass is melted quickly, distortion of the optical fiber due to large differences in coefficient of linear coefficient between the respective constructive components during cooling becomes considerable and that, in either of the above-mentioned two cases, the thermal influence to the optical fiber becomes worse.

The tablet 3 of low melting point glass is formed by sintering and includes voids. Therefore, when melted, its apparent volume is reduced. According to the present method, the glass pipes 5 arranged in the opposite end portions of the metal pipe 4 are pushed in, respectively, when the tablet 3 is melted, so that any void in the molten low m lting point glass is prevented from forming inside the metal pipe 4 and hence the intimate contacts b tw en the metal pipe 4 and the low melting point glass tablet 3 and between th tablet 3 and the optical fiber 1 are obtained, making the airtight seal of th optical fiber lead portion mor r liabl .

The step of pushing the glass pipes 5 into th metal pipe 4 in order to at least reduce void formation in the molten low melting point glass 3 realiz s s v ral favorabl ffects. That is, wh n th optical fib r is a polari-

zation maintaining fiber, degradation of polarization due to uneven stress on a side surface of the optical fiber is avoided. Further, breakage of the optical fiber due to uneven str ss is avoided. In addition, since there is no probable leakage of air through void portions, the reliability of airtightn ss is improved.

Fig. 4 is a longitudinal cross section of the optical fiber lead portion which is airtightly sealed as described above.

Since, in this embodiment, there is the glass pipes 5 between the metal pipe 4 and the protective coating 2 of the optical fiber 1, heat generated in the metal pipe 4 is blocked by the glass pipes 5 to transmit to the protective coating 2. As a method for more reliably blocking heat transmission from the metal pipe 4 to portions of the protective coating 2 within the glass pipes 5 outside the metal pipe 4, a cooling mechanism is provided around the portions of the glass pipes 5. Further, since the glass pipes 5 cover the portions of the protective coating 2 enough, it is possible to complete the melting step of low melting point glass without exposing the optical fiber 1. It should be noted that the glass pipes 5 have a positioning function of fixing the optical fiber 1 at a center of the through-hole of the metal pipe 4. Therefore, the optical fiber 1 is fixed in substantially the center position of the metal pipe 4 even when the low melting point glass material 3 is melted.

In this embodiment, diameter of the metal pipe 4 is 2 x 10 mm (inner diameter is 1 mm) and diameter of the glass pipe 5 is 1 x 5.5 mm (inner diameter is 0.3 mm). Length of the portions of the glass pipe 5 which protrude from the opposite ends of the metal pipe 4 are 1 mm, respectively. Length of the exposed portion of the optical fiber 1 measured from each end of the metal pipe 4 is 0.5 mm and therefore the exposed portion is completely protected by the glass pipes.

Further, since protection of the optical fiber 1 having the protective coating against bending thereof can be improved by providing chamber 5a on the opening portion of the glass pipe 5, there is no need of additional machining therefor. Such chamfering of the glass pipe 5 can be achieved by coating the outside surface of the glass pipe 5 with a resist and etching it by dipping the glass pipe in a solution of such as hydrofluoric acid. In this embodiment, the glass pipe 5 is of borosilicate glass having melting point higher than that of the low melting point glass 3. Physical properties of the low melting point glass and the glass pips 5 are shown in Table 1.

TABLE 1

material	item	properties
low melting glass	sealingly fixing temperature	430°C
	coefficient of linear expansion	41×10^{-7}/°C
glass pipe	softening point	720°C
	coefficient of linear expansion	46×10^{-7}/°C
	heat conductivity	0.0269 cal/cm·sec. °C

The metal pipe 4 in this embodiment is of SUS304 or KOVAR. The metal pipe 4 of SUS304 is suitable when the metal pipe 4 in which the optical fiber 1 is fixed by the low melting point glass is to be welded to a casing by using a YAG laser. Fig. 7 is a longitudinal cross section of an airtight seal structure of the optical fiber according to the present invention which is realized by inserting the airtight seal portion of the optical fiber prepared as mentioned above into a hole 13 formed in a side surface of the casing 12 and then seam-welding the metal pipe 4 thereof to the casing 12. In this embodiment, the metal pipe 4 may be substituted by a ceramic pipe, in which case, the fixing and airtight seal to the casing 12 can be done by soldering.

On the other hand, KOVAR is superior for the metal pipe 4 in that, due to its coefficient of linear expansion close to that of glass, it can reduce stress to the optical fiber. For this reason, the metal pipe 4 of KOVAR is effective when the optical fiber is such as polarization maintaining fiber which is easily influenced by stress. This is because it is through that coefficient of linear expansion of the metal pipe has an intimate relation to compressive force exerted on the optical fiber and therefore the use of KOVAR whose coefficient of linear expansion is small contributes to reduction of compressive stress of the optical fiber. Thus, the material of the metal pipe 4 may be selected from them. However, the metal pipe 4 may be of any other material so long as the latter can provide a good contact with the glass material. Although, in this embodiment, a pair of glass pipes is used, it is possible to use a single glass pipe for airtight seal.

A second embodiment of th present invention wll be described with reference to Fig. 8. The second embodiment is featured by a glass pipe 51 having opposite ends which are made in contact with ends of a pair

of metal pipes 51, respectively.

Although, in th previously described first embodim nt, the metal pipe 4 must be long enough to receive the portions of the glass pipes 5 inserted into the metal pipe, length of the metal pipe 41 in the second embodiment can be as short as the irreducible minimum necessary for an airtight seal by means of low melting point glass material 3 since glass pipes 51 are fixed to the metal pipe 41 with their end faces being in direct contact with respective opposite ends of the metal pipe 41. Further, diameter of the metal pipe 41 can be reduced up to diameter of the glass pipe 51. Therefore, leakage of heat during heating of the metal pipe 41 is reduced and hence it is possible to melt the low melting point glass material 3 efficiently. As a result, it becomes possible to minimize an amount of heat given to the metal and thus thermal influence to a protective coating 2 can be minimized. The fixing between the metal pipe 41 and the glass pipes 51 is performed by the low melting point glass 3 as in the first embodiment.

Further, in the second embodiment, it is possible to improve a protection of an optical fiber in lateral direction by chamfering the end portions of the glass pipes 51, making a terminal processing in a later step unnecessary.

In the airtight seal method for an optical fiber leading portion according to the second embodiment of the present invention, the assembly of the metal pipe and the glass pipes whose melting point is higher than that of the low melting point glass material has the through-hole for receiving protected portions and an exposed portion of the optical fiber and the low melting point glass material fills an annular space between an inner wall of the metal pipe and the exposed portion of the optical fiber. Since both the airtight seal and the fixing of the glass pipes to the metal pipe are performed by heating the metal pipe having the opposite ends in contact with the respective ends of the glass pipes to melt the low melting point glass material in the space, it is possible to prevent large heat transmission the metal pipe to the optical fiber and the protective coating thereof, so that the optical fiber can be airtightly sealed without degradation of its optical characteristics.

Further, since it is possible to reliably position the optical fiber precisely, the resultant optical fiber leading portion is stable. Further, due to the merit of simultaneous fixing of the low melting point glass and the glass pipes, any protective step for protecting the exposed optical fiber becomes unnecessary, simplifying the manufacture thereof. As a result, the workability during manufacture is improved and therefore an inexpensive and mass-producible optical fiber leading portion can be obtained.

Further, since length of the metal pipe can be very short, heat for melting the low melting point glass within the space mentioned above can be used efficiently without unnecessary external heat radiation. Therefore, damage of the protective coating of the optical fiber can be minimized and hence its length required for the leading portion can be minimized without sacrificing its function of protecting the optical fiber. Thus, it is possible to miniaturize the whole structure.

Since the minimum length of the optical fiber leading portion necessary to achieve the airtight seal thereof is a sum of length for airtight seal and length necessary to fix the glass pipes, it is possible to reduce the length of the metal pipe down to about 2 mm. Since reduction of length of the metal pipe leads to reduction of heat to be added to the metal pipe, it is possible to further reduce the thermal influence to the optical fiber and to reduce length of the exposed portion of the optical fiber.

These merits are considerable when compared with the conventional metal pipe which is as long as 20 mm or more in order to reduce thermal influence to the optical fiber by separating a portion of the metal pipe to which heat is added from the optical fiber by as a large distance as possible.

In a case where ceramic pipes are used instead of the glass pipes in the second embodiment, although heat flow from the metal pipe due to air flow can be blocked, the thermal influence to the optical fiber becomes larger compared with the case of the glass pipes since heat conductivity of ceramics is 0.05 cal/cm·sec. °C which is higher than that of the glass pipe. Further, the use of glass pipes is preferable in view of bonding thereof to the metal pipe through the low melting point glass in fixing them to the metal pipe.

Claims

1. An airtight seal structure of an optical fiber leading portion of an optical device, comprising:

   an optical fiber (1);

   a pipe member (4) having a through-hole for receiving said optical fiber inserted thereinto, for connecting an interior of said optical fiber (1) leading portion to an exterior of said optical fiber (1) l ading portion;

   at l ast one glass pip (5) having a through-hole for receiving said optical fiber (1) inserted ther into and insert d into said pip means (4); and

   a low melting point glass material (3) disposed within said pip means (4) in th vicinity of an end

face of said glass pipe (5) and filling a space defined by an inner wall of said pipe member (4) and said optical fiber (1) when melted by heating to thereby airtightly seal said interior of said optical fiber (1) leading portion against said xterior of said optical fiber (1) leading portion within said pip member (4).

2. An airtight seal structure of an optical fiber leading portion of an optical device, claimed in claim 1, wherein melting point of said glass pipe (5) is higher than that of said low melting point glass material (3).

3. An airtight seal structure of an optical fiber leading portion of an optical device, claimed in claim 2, wherein an outer surface of said glass pipe (5) is fixed to said inner wall of said pipe member (4) by said low melting point glass material (3).

4. An airtight seal structure of an optical fiber leading portion of an optical device, claimed in claim 3, wherein said low melting point glass material (3) is positioned in said interior of said leading portion with respect to said glass pipe (5).

5. An airtight seal structure of an optical fiber leading portion of an optical device, claimed in claim 3 or 4, wherein the end surface of said glass pipe (5) is protruded from the end of said pipe member (4).

6. An airtight seal structure of an optical fiber leading portion of an optical device, as claimed in any of claims 3 to 5, wherein two of said glass pipe (5) are provided and said low melting point glass is material (3) disposed between said two glass pipes (5).

7. An airtight seal structure of an optical fiber leading portion of an ottical device, as claimed in any of claims 1 to 6, wherein said pipe member (4) is of metal material (3).

8. An airtight seal structure of an optical fiber leading portion of an optical device, as claimed in any of claims 1 to 6, wherein said pipe member (4) is of ceramics.

9. An airtight seal structure of an optical fiber leading portion of an optical device, claimed in claim 6, wherein said optical fiber (1) is coated with a protective coating (2) and wherein a portion of said protective coating (2) is removed in the vicinity of said optical fiber (1) to which said low melting point glass material (3) is bonded.

10. An airtight seal structure of an optical fiber leading portion of an optical device, as claimed in any of claims 3 to 9, wherein said glass pipe (5) has an outer diameter larger than a diameter of said through-hole of said pipe member (4) and an end face in face to face contact with an end face of said pipe member (4).

11. An airtight seal structure of an optical fiber leading portion of an optical device, as claimed in any of claims 3 to 10, wherein a peripheral edge portion of said through-hole of said glass pipe (5) is chamfered.

12. An airtight seal structure of an optical fiber leading portion of an optical device, as claimed in any of claims 1 to 11, wherein said low melting point glass material (3) is borosilicate glass.

13. An airtight seal structure of an optical fiber leading portion of an optical device, as claimed in any of claims 1 to 12, wherein said optical fiber (1) is a polarization maintaining fiber.

14. An airtight seal structure of an optical fiber leading portion of an optical device, as claimed in any of claims 1 to 7 and 9 to 13, wherein said pipe member (4), after said low melting point glass material (3) is melted, is inserted into a hole (13) formed in a side surface of a casing and having a diameter slightly larger than the outer diameter of said pipe member (4) and a portion of said casing around said hole (13) is fixed to an outer periphery of said pipe member (4) by welding.

15. An airtight seal structure of an optical fiber leading portion of an optical device, comprising:

an optical fiber (1);

a pipe member (4) having a through-hole for receiving said optical fiber (1) inserted thereinto, for connecting an interior of said optical fiber (1) leading portion to an exterior of said optical fiber (1) leading portion;

at least one glass pipe (5) having a through-hole for receiving said optical fiber (1) inserted thereinto and an outer diameter larger than an inner diameter of said pipe member (4), said glass pipe (5) being in

contact with at least an end face of said pipe member (4); and

a low melting point glass material (3) disposed within an annular space defined by an inner wall of said pipe member (4) and said optical fiber (1) and filling said space when melted by heating to ther by airtightly seal said interior of said optical fiber (1) leading portion against said exterior of said optical fiber (1) leading portion within said pipe member (4).

16. A method of airtightly sealing an optical fiber leading portion of an optical device, comprising the steps of:

inserting an optical fiber (1) into a first glass pipe (5) and inserting said first glass pipe (5) into said pipe member (4);

mounting a tablet of low melting point glass (3) on said optical fiber (1) in said pipe member (4); and

heating an outer periphery of said pipe member (4) to melt said tablet (3).

17. A method of airtightly sealing an optical fiber leading portion of an optical device, comprising the steps of:

inserting an optical fiber (1) into a first glass pipe (5) and inserting said first glass pipe (5) into said pipe member (4);

mounting a tablet of low melting point glass (3) on said optical fiber (1) in said pipe member (4);

fitting a second glass pipe (5) on said optical fiber (1) from the side thereof on which said tablet (3) is mounted and inserting said second glass pipe (5) into said pipe member (4);

heating an outer periphery of said pipe member (4) to melt said tablet (3);

exerting inward pressure to outer end faces of said first and second glass pipes (5); and

cooling said pipe member (4).

18. A method of airtightly sealing an optical fiber leading portion of an optical device, claimed in claim 17, wherein said optical fiber (1) has a protective coating (2), further comprising, before the step of inserting said optical fiber (1) into said pipe member (4), the step of removing a portion of said protective coating (2) of said optical fiber (1) to which said low melting point glass material (3) is bonded.

19. A method of airtightly sealing an optical fiber leading portion of an optical device, as claimed in any of claims 16 to 18, wherein a melting point of said glass pipe (5) is higher than that of said low melting point glass material (3).

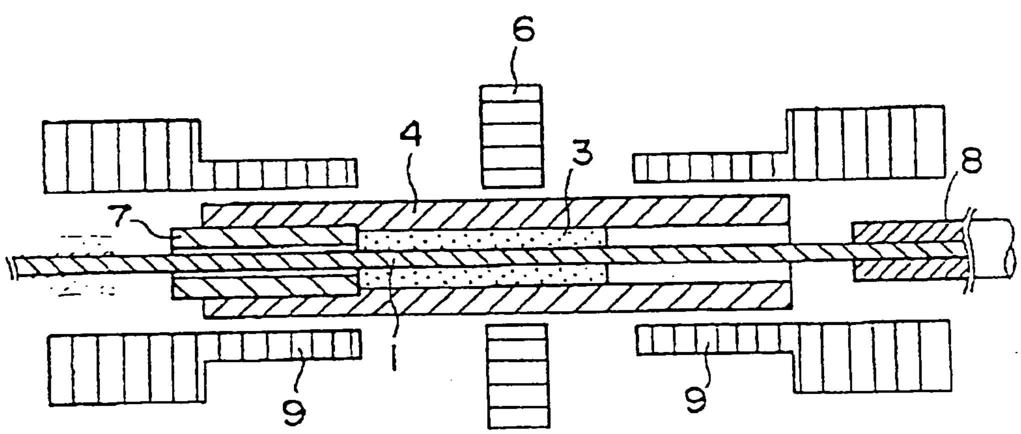
20. A method of airtightly sealing an optical fiber leading portion of an optical device, as claimed in any of claims 16 to 19, wherein, in the step of heating said pipe member (4), temperature of said pipe member (4) is in a range from 500°C to 560°C and heating time is in a range from 20 seconds to 90 seconds.

21. A method of airtightly sealing an optical fiber leading portion of an optical device, as claimed in any of claims 16 to 19, wherein temperature of said pipe member (4) by heating thereof is in a range from 540°C to 600°C and heating time is in a range from 20 seconds to 60 seconds.

22. A method of airtightly sealing an optical fiber leading portion of an optical device, as claimed in any of claims 16 to 21, wherein said heating of said pipe member (4) is performed by a high frequency induction heater (6) arranged around of said pipe member (4).

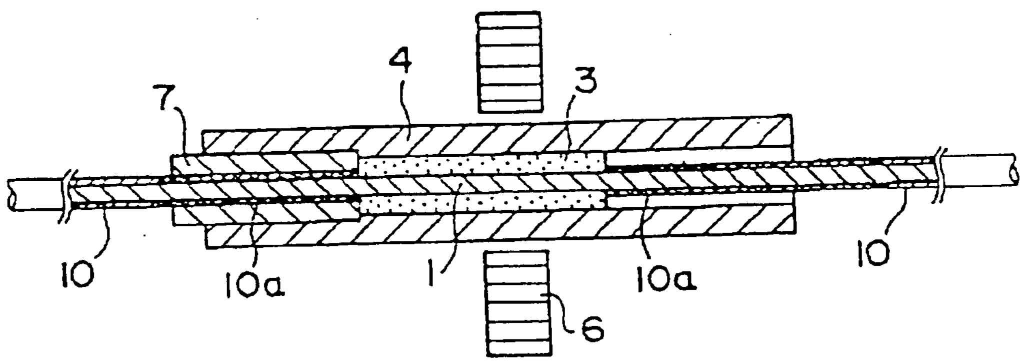
23. A method of airtightly sealing an optical fiber leading portion of an optical device, as claimed in any of claims 17 to 22, further comprising, after the cooling step, the steps of inserting said pipe member (4) into a hole formed in a side surface of a casing and having a diameter slightly larger than an outer diameter of said pipe member and fixing a portion of said casing around said hole to an outer periphery of said pipe member (4) by welding.

FIG. 1



PRIOR ART

FIG. 2



PRIOR ART

FIG. 3

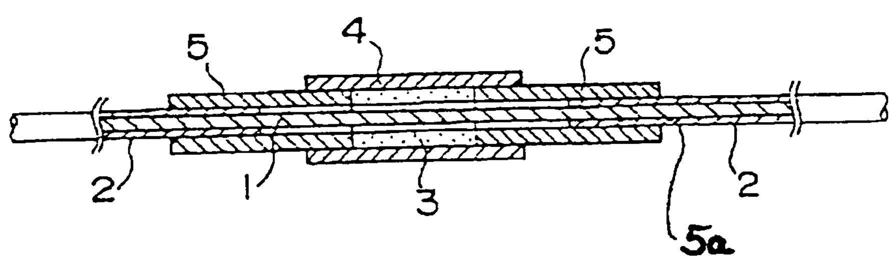
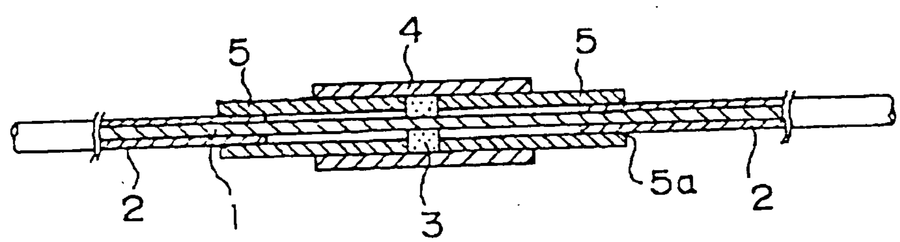


FIG. 4



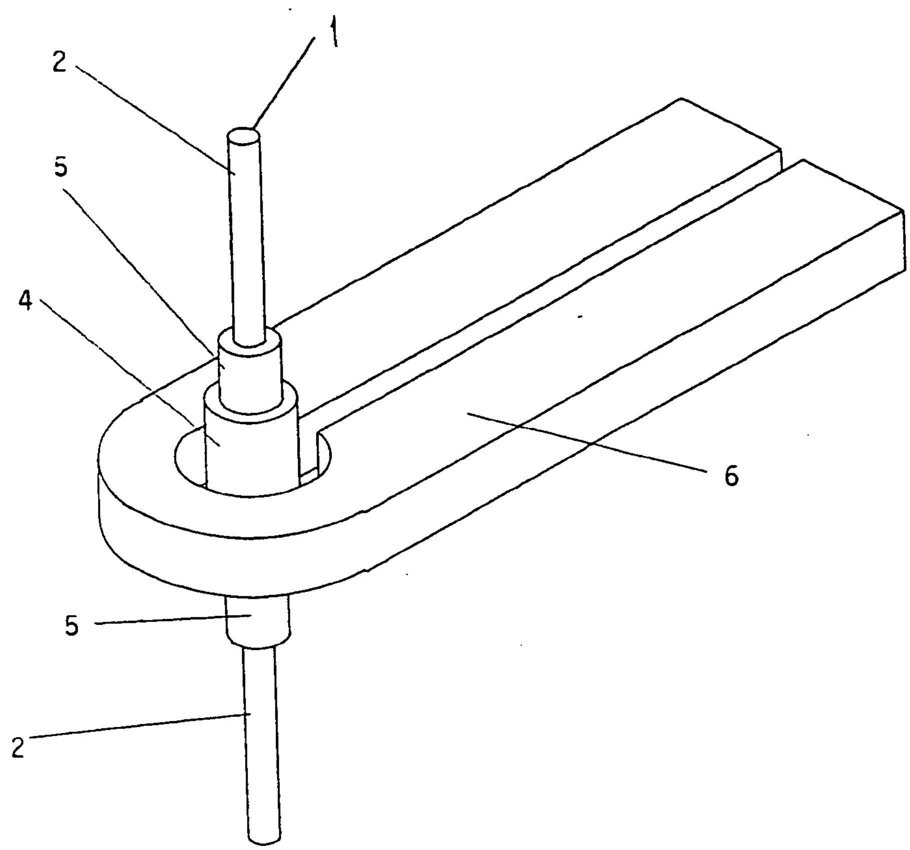


FIG. 5

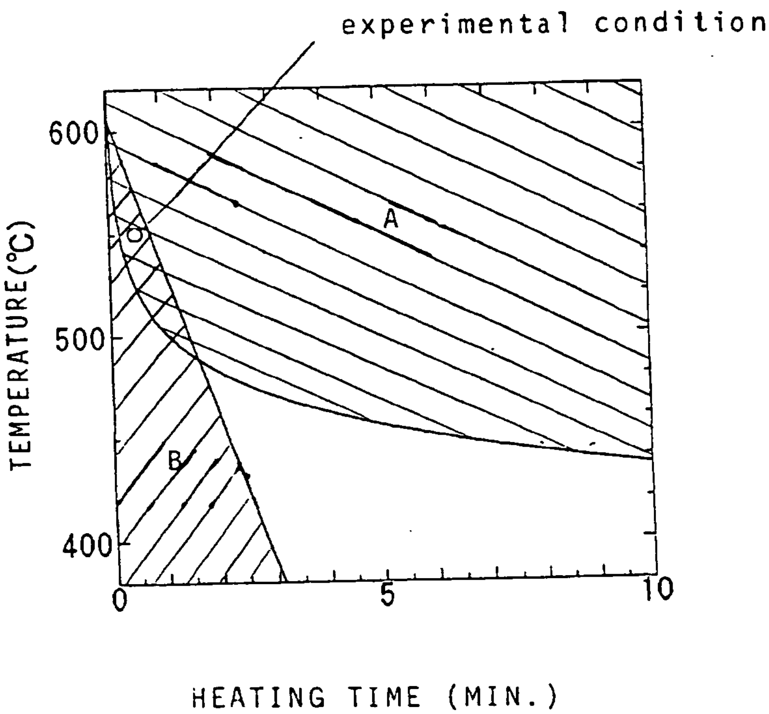

experimental condition
600
500
400
TEMPERATURE(°C)
A
B
0
5
10
HEATING TIME (MIN.)

FIG. 6

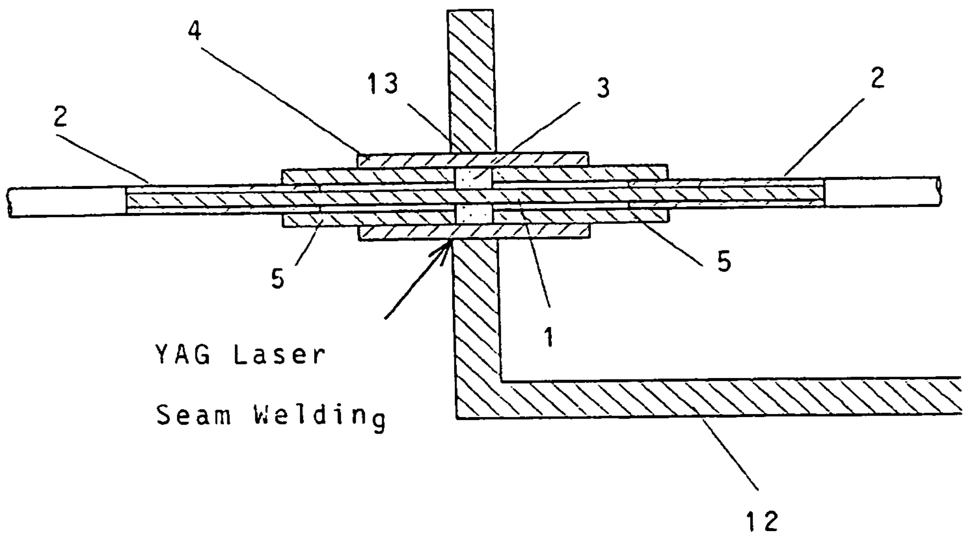
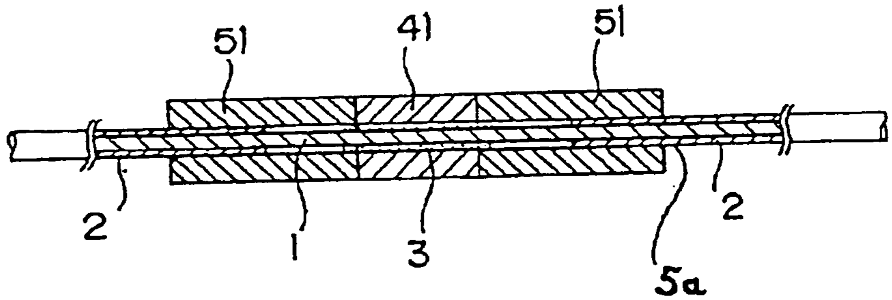


FIG. 7

FIG. 8



European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 94 10 1284

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
A	EP-A-0 332 046 (SCHOTT) * abstract * * page 5, line 11 - line 18 * * column 5, line 44 - column 6, line 19 * * figure 3 * ---	1,15-17	G02B6/00 G02B6/42
A	EP-A-0 449 591 (NGK) * abstract * * figure 1 * ---	1,15-17	
A	DE-A-37 41 773 (J. GUTTMANN) * column 2, line 7 - line 54 * * figure 2 * ---	1,15-17	
A	EP-A-0 274 222 (BRITISH TELECOMMUNICATIONS) * page 4, line 20 - line 23 * * page 5, line 9 - line 13 * * figure 3 * ---	1,15-17	
A	EP-A-0 337 141 (SIEMENS) * abstract * * figure 1 * ---	1,15-17	TECHNICAL FIELDS SEARCHED (Int.Cl.5) G02B
A	WO-A-91 14958 (BT&D TECHNOLOGIES) * abstract * * figure 1 * ---	1,13	
A	DE-A-41 18 491 (DAIMLER-BENZ) * abstract * * figure 2 * -----	1,14	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	17 May 1994	Luck, W

CATEGORY OF CITED DOCUMENTS

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